

Organization(s): Naval Research Laboratory

Title: Unsteady Flow Through Microfluidic Devices

Duration of Effort: March 1998 - March 2000

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Objectives:

Develop, demonstrate, and apply state-of-the-art computational technology for describing the physics of unsteady fluid flows through microfluidic devices. Compute the effects on microfluidic flow and device operation of large moving components, particulates, particle agglomeration, and biomolecules travelling through the system. Compute the effects of high Knudsen number flow on microdevice operation.

Major Accomplishments:

- Developed methods for solving low-velocity, high Knudsen number gaseous microflows.
- Quantified the effects of temperature scaling and demonstrated the use of a monotone filter to successfully remove statistical noise from low velocity DSMC solutions.
- Applied DSMC computations to evaluate scaling laws for gaseous microfilter performance and derived a modified scaling law including Knudsen-number effects.
- Demonstrated the use of 3-D unsteady flow computations for liquid flows in microchannels. Flows included straight rectangular microchannels, microchannels with moving valves, spherical obstacles, and biomolecules moving through valves. Improved automatic mesh generation capability developed for surface meshing of hundreds of multiple intersecting surfaces with subsequent automatic volume mesh generation for use with biomolecular flow computations. Quantified effects of microbead-wall interaction on flow in microchannels.

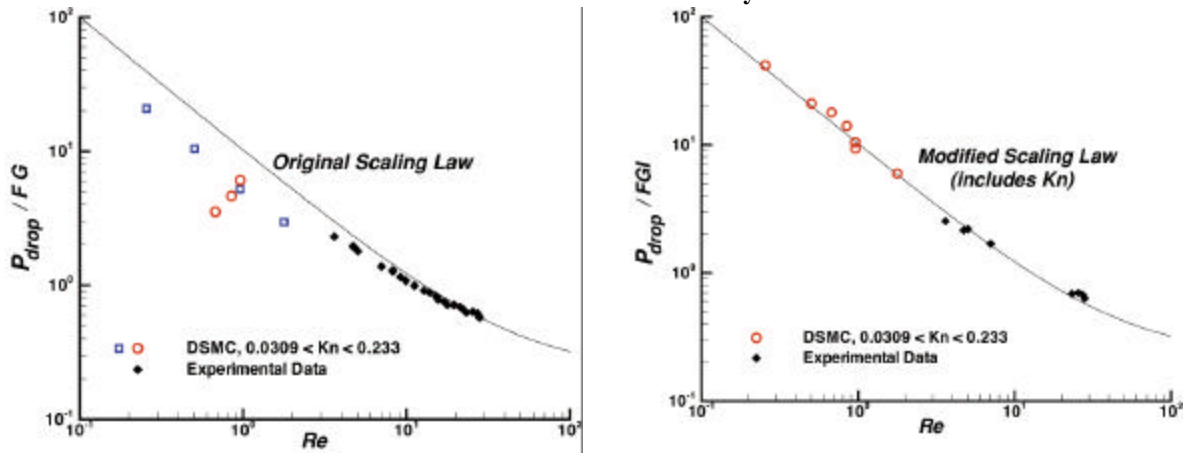
DOD Impact:

- Microfilter scaling laws useful in optimizing the isolation of biological and chemical agents.
- Microfilter scaling laws useful as a parametric component model in system-level simulation.
- Performance assessment of MEMS devices from first principles is available to evaluate novel concepts for which no parametric models exist.
- DoD High Performance Computing and Modernization Office (HPCMO) now sponsoring a DSMC software development program.

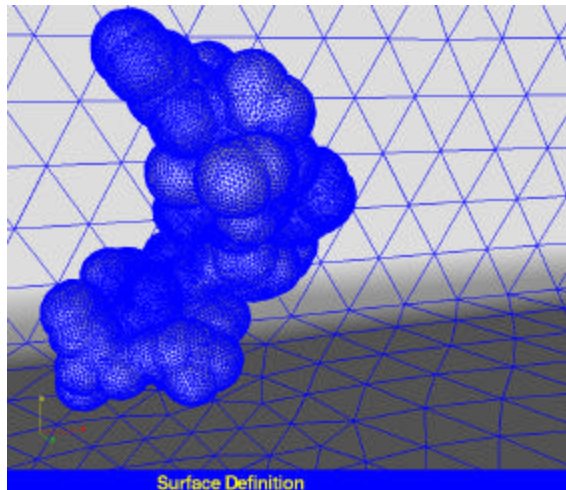
Technology Transfer/Products:

- Produced enabling computational technology for design of novel MEMS devices with obstacles and actuators.
 - Produced an automatic unstructured grid generation code for multiple intersecting surfaces.
 - Produced scaling relationships for evaluation of gas micropore filter geometries.
 - Developed new method that can be applied to a wide range of particle-based methods for reducing the effects of statistical noise in any stochastic calculation.
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The original scaling law for predicting pressure drop across microfilters was developed by groups led by C.M. Ho (UCLA) and Y.C. Tai (Caltech) under the DARPA MICROFLUMES program based on continuum experiments and calculations. High Knudsen-number flows did not follow this law (left), so the scaling law was modified (right) to include nonequilibrium effects. P_{drop} is pressure drop normalized by freestream dynamic pressure. Terms in the scaling law: F depends solely on the ratio of open area (holes in the filter) to total filter area, G is a function of the ratio of filter thickness to the average hole diameter, H is a function of the Reynolds number (Re), and I is a function of the Knudsen number, Kn .



A new automatic unstructured grid generation code was developed to produce a surface mesh for an arbitrary number of intersecting surfaces. This surface mesh was the front for the generation of a volume mesh which was then used for a finite element flow computation. The self-consistent trajectory of a rigid biomolecular fragment was computed as it translated and rotated in a pressure-driven flow under a microvalve opening. The surface meshes are shown. The increased mesh resolution is seen under the valve as provided by the adaptive re-meshing within the flow solver.